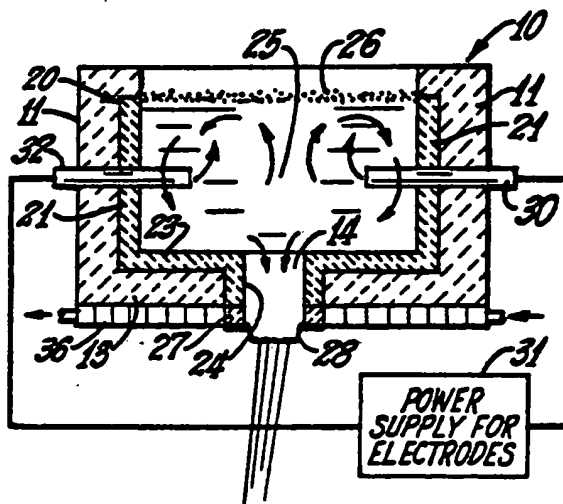




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(54) Title: ELECTRIC GLASS MELTING FURNACE

**(57) Abstract**

A glass heating method and apparatus, such as a glass melting furnace (10) or a forehearth, utilizing a refractory lining (20, 21 and 23) and electrically energized heating electrodes (30 and 32). The refractory lining (20, 21 and 23) is an erosion resistant material, preferably a chromic oxide refractory, having an electrical resistivity which is less than the resistivity of the molten glass, preferably an E glass, which is being heated. To avoid short-circuiting through the low resistance refractory (20, 21 and 23), the refractory (20, 21 or 23) interposed between electrodes of opposite polarity is cooled to a temperature less than the temperature of the molten glass and at which the resistivity of the refractory (20, 21 or 23) is materially increased. Where the electrodes (30 or 32) of opposite polarity are carried by opposing side walls (11), the end and/or side walls of the apparatus are cooled. Where the electrodes are all carried by a single wall, that wall is cooled.

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ELECTRIC GLASS MELTING FURNACE

D E S C R I P T I O NTECHNICAL FIELD

In the electric heating of molten glass, it is conventional to confine the glass in a heating receptacle, such as a melting furnace or a forehearth, which is lined with a refractory. The heating electrodes project through the refractory walls, usually either the side walls or the bottom wall, into the pool of molten glass in contact with the refractory lining. The electrodes, of course, are of opposite polarity, and the glass is heated between the electrodes by the current flowing between the electrodes.

BACKGROUND ART

Many different electrode arrangements have been proposed in the prior art to vary the electrode heating effects within the molten glass pool. One such arrangement utilizes electrodes carried by the opposing side walls of a melter or forehearth, the electrodes of each side wall being of the same polarity and the electrodes of the opposing walls being of opposite polarity. The resultant thermal current is used to heat the entire molten glass pool.

Another arrangement of heating electrodes involves the insertion of heating electrodes of different polarity through a single refractory lined wall, usually a bottom wall, for example, as shown in U. S. Patents Nos. 3,757,020 and 3,392,237.

The refractory lining of such furnaces necessarily is electrically conductive to a greater or



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1 lesser degree, and the conventional electric furnace
requires the utilization of a refractory which is less
conductive than the molten glass. Expressed in terms of
electrical resistivity, the effective electrical
5 resistivity of the refractory must be sufficient relative
to the resistivity of the molten glass at the operating
temperature of the glass heating apparatus to avoid any
appreciable short-circuiting of the heating current through
the refractory rather than through the molten glass. For
10 this reason, zircon-type refractories of high resistivity
have been utilized in electrical glass heating apparatus.

However, such zircon-type refractories are
incompatible with certain glasses, such as E and C glass
compositions, and are prone to erosion from such molten
15 glass compositions flowing through the heating apparatus.
Any electric glass heating apparatus utilizing such
refractories with incompatible glass compositions has a
notoriously short life. As a result, conventional electric
glass heating apparatus has been limited to compatible,
20 usually easily melted glasses, e.g., those glasses
containing appreciable amounts of sodium oxide or the like,
or to low throughput applications or to booster
applications as a supplement to primary combustion heating.

The utilization of refractories of higher erosion
25 resistance, such as chromic oxide refractories, has not
been practical because such refractories have an electrical
resistivity that is appreciably less than the resistivity
of the molten glass at the furnace operating temperatures.
As a result, such refractories short-circuit, and the
30 electric current flow through the refractory heats the
refractory, so that the heating apparatus lining wears
excessively and sloughs off into the molten glass causing
stoning in the glass. Eventually the refractory melts from
the heating current flowing through the refractory.

35 Thus, the use of a chromic oxide refractory has
not been practical although it has a service life which may
be 7-10 times as great as the conventional zircon



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1 refractory when in contact with molten E glass, for
example.

DISCLOSURE OF THE INVENTION

5 The present invention now proposes a method and
apparatus for electrically heating glass utilizing
refractories which have high erosion resistance and low
electrical resistivity by cooling the refractory to a
temperature at which the resistivity of the refractory is
increased and the tendency of short-circuiting through the
10 refractory is appreciably reduced.

The heating apparatus may be a melting furnace
having a pool of molten glass surmounted by a layer of
unmelted batch, the pool being confined by
electrode-bearing side walls joined by end walls and a
15 bottom wall with the electrodes of opposing side walls
being of opposing polarity. The side, end and bottom walls
are all lined with an erosion-resistant refractory, e.g., a
chromic oxide refractory, the electrical resistance of
which varies inversely with the operating temperature and
20 which has an electrical resistivity, at the temperature of
the molten glass, which is less than the resistivity of the
molten glass.

The heating apparatus, alternatively, may be a
forehearth for conveying molten glass from a melting
25 furnace to a forming apparatus. Here, the forehearth has
side walls through which the electrodes extend into the
molten glass stream to compensate for heat losses from the
molten glass stream. Preferably, the side and bottom walls
of the forehearth are lined with a similar
erosion-resistant, low resistivity refractory.
30

As a third alternative, the heating apparatus may
be a melting furnace in which all of the electrodes project
through a single wall, e.g., the bottom wall. Such
bottom-entering electrodes of different polarity are
35 energized electrically to heat the glass above the bottom
wall, and the bottom wall as well as the side walls are
lined with erosion-resistant, low resistivity refractory.



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1 The present invention proposes the cooling of
that low resistivity refractory of the heating apparatus
which is effectively interposed between electrodes of
differing polarity to increase the electrical resistivity
5 of the refractory and to reduce the tendency of the
refractory to short-circuit in operation.

In a melting furnace, as above described, where
the electrodes are carried by the respective side walls,
the refractory tends to short-circuit primarily through the
10 end walls beneath the upper level of the molten glass. By
cooling the end walls, the resistivity of the refractory of
the end walls is materially increased, and short-circuiting
is reduced. Similarly, the bottom wall may be cooled to
reduce the tendency for short-circuiting through the bottom
15 wall.

In a bottom electrode melting furnace, the
electrodes of the bottom wall are of different polarity,
and cooling of the bottom wall will reduce the tendency
toward short-circuiting through the bottom wall between
20 electrodes of opposite polarity.

In a forehearth, cooling of the bottom wall
increases the resistivity of the refractory of the bottom
wall and reduces short-circuiting by current flow through
the bottom wall.

25 By increasing the resistivity of the refractory,
it becomes possible and practical to utilize chromic oxide
refractories and similar refractories of enhanced erosion
resistance, despite their inherent low electrical
resistivity, so that the throughput of the heating
30 apparatus can be increased, and the heating and melting
efficiency of the apparatus is also increased. The amount
of cooling of the side walls is sufficient to increase the
electrical resistivity of the refractory to a value at
which short-circuiting through the refractory is reduced,
35 but not so great as to materially reduce the temperature of
the molten glass being heated.



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1 This is particularly applicable to glass melting
furnaces of the type having side wall entering electrodes
since the molten glass is heated primarily above the
electrodes by electrode-generated currents. In such a
5 furnace, the heated molten glass circulates primarily
vertically upwardly from the central space between the
electrodes against the overlying batch blanket and then
downwardly along the furnace side walls. Cooling of the
end walls and the bottom wall for the purposes of the
10 present invention does not materially chill the molten
glass because of its rapid, circulatory motion well above
the bottom wall and along the non-chilled side walls.

 Similarly, the cooling of the bottom wall of a
forehearth or the bottom wall of a furnace having bottom
15 entry electrodes does not materially decrease the
temperature of the molten glass because the heated molten
glass moves vertically upwardly from the electrode ends and
away from the bottom wall.

 In any event, if the molten glass body is cooled
20 undesirably, the operating temperature of the heating
apparatus can be increased to compensate for any molten
glass temperature reduction caused by the chilling of any
wall for the purpose of increasing refractory resistivity.

 The cooling of the refractory lining is effective
25 to reduce the short-circuit heating of the refractory to a
level at which the refractory does not melt nor slough off
into the molten glass body, but it may not prevent all
short-circuiting through the refractory. However, the
small amount of short-circuiting which does occur merely
30 imparts a minor degree of heat to the refractory, and
neither the refractory life nor the heating efficiency of
the apparatus is materially affected.

 Further, the tendency to short-circuit through
the refractory is directly, apparently linearly related to
35 the distance through which the current must flow. The
primary heating path is from one electrode tip to the
opposing electrode tip of opposite polarity while the



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1 short-circuit path is peripheral to the pool of molten
glass and through the refractory. Where the refractory
path is from one electrode through an end wall to the other
5 electrode or from one electrode through the bottom wall to
the opposing electrode, the path for short-circuiting is
always materially greater than the primary
electrode-to-electrode heating path through the molten
glass. As a result, it is not necessary to reduce the
10 temperature of the refractory to the extent theoretically
necessary to prevent any short-circuiting.

Thus, the refractory need not be cooled to such
an extent that its electrical resistivity is increased to
the numerical value of the electrical resistivity of the
glass. It is only necessary to cool the refractory to an
15 extent such that its electrical resistivity is increased
sufficiently to prevent substantial short-circuiting
through the refractory path as compared to the
electrode-to-electrode current path.

BRIEF DESCRIPTION OF DRAWINGS

20 Figure 1 is a schematic plan view of a glass
melting furnace of the present invention capable of
carrying out the method of the present invention;

Figure 2 is a vertical sectional view taken along
the plane 2-2 of Figure 1;

25 Figure 3 is a vertical sectional view taken along
the plane 3-3 of Figure 1;

Figure 4 is a vertical sectional view similar to
Figure 2 showing the invention as embodied in a forehearth
channel;

30 Figure 5 is a plan view similar to Figure 1 but
illustrating the invention as embodied in a melting furnace
having bottom entering electrodes;

Figure 6 is a vertical sectional view of that
version of the invention illustrated in Figure 5 of the
35 drawings;

Figure 7 is a graphic representation of the
relative electrical resistivity of a chromic oxide



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1 refractory and molten E glass at varying temperatures; and

Figure 8 is a graphic representation similar to Figure 7 showing the relative electrical resistivity of a different chromic oxide refractory and molten C glass.

5 BEST MODE OF CARRYING OUT INVENTION

As illustrated in Figures 1 through 3 of the drawings, the present invention is incorporated into a melting furnace 10.

More specifically, the furnace 10 comprises
10 peripheral refractory side walls 11, end walls 12 and a bottom wall 13 formed of suitable refractory material and retained in position by appropriate supporting metal framework and foundations (not shown). The bottom wall is provided with a generally rectangular outlet opening 14.
15 Preferably, the lining 11 is a conventional refractory identified in the art as a sintered zircon refractory having substantially the following composition:

	<u>Ingredient</u>	<u>% by Weight</u>
	ZrO ₂	65.5
20	Al ₂ O ₃	0.5
	Fe ₂ O ₃	0.1
	TiO ₂	0.3

The refractory side walls 11, end walls 12 and bottom wall 13, including the bottom wall opening 14 are
25 lined with an erosion-resistant, but low-resistivity refractory, preferably a dense chromic oxide refractory, indicated generally at 20 and including side wall portions 21, end wall portions 22, bottom wall portions 23 and an opening lining portion 24 which, in cooperation, form a
30 complete lining for an interior space 25 for containing a body of molten glass. It will be noted that the side wall lining 21 and the end wall lining 22 extend vertically throughout the extent of the molten glass pool space 25 but terminate short of the upper ends of the side walls 11 and
35 end walls 12. The pool of molten glass in the space 25 is surmounted by a blanket of unmelted, particulate glass batch 26.



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1 The side walls 11 and the side wall lining 21 are
pierced by heating electrodes 30 which are connected to a
power supply as indicated schematically in Figure 2. The
electrodes 30 piercing each end wall 11 and lining 21 are
5 of the same relative polarity while the electrodes 32
piercing the opposite side wall 11 and lining 21 are of
relatively reversed polarity. The power supplied from the
power supply 31 supplies heating current to the electrodes
30 and 32 to heat the body of molten glass in the space 25.

10 As illustrated in Figures 1 and 2 of the
drawings, an outlet opening 14 circumscribed by the
refractory portions 14 and 24 is provided in the bottom of
the furnace, and this opening 14 communicates through a
bushing block 27 with a lower forming apparatus 28,
15 illustrated in the form of a bushing for forming filaments
of fiberglass, which filaments are drawn downwardly about a
collection roller 29 to a conventional winder (not shown).

 The heating of the molten glass in the space 25
occurs primarily between the inboard ends of the electrodes
20 30 and 32, and heated molten glass between the electrodes
rises vertically within the space 25 upwardly into contact
with the undersurface of the batch blanket 26 due to the
convection currents generated by the hottest glass between
the electrode ends. The rising hot molten glass then flows
25 outwardly along the undersurface of the batch blanket 26
and then downwardly along the outer wall linings 21, 22
back to the location of the electrodes 30, 32.

 Some of the downwardly flowing glass flows past
the electrode location downwardly toward and through the
30 outlet opening 14 and the bushing block 27 into the forming
apparatus 28. Due to the rising convection currents
generated between the electrodes 30 and 32, the hottest
glass of the molten glass pool within the space 25 is
located generally above the location of the electrodes 30
35 and 32, and this glass is circulated and recirculated by
convection from the electrodes 30 and 32 to melt the batch
blanket 26. A minor amount of the thermally recirculated



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1 glass equal to the throughput of the bushing 28 flows
downwardly past the electrodes. This quantity of glass is
cooled in successive isothermal planes to the desired
temperature for introduction into the bushing. Thus, the
5 glass beneath the electrodes 30 and 32 is generally cooler
than the glass above the electrodes 30 and 32, and this
cooler glass flows through the substantially isothermal
planes downwardly through the outlet opening 14 and the
bushing block 27 into the bushing 28.

10 As illustrated in Figures 7 and 8 of the
drawings, these differences in electrical resistivity may
be readily ascertained. In Figure 7, the electrical
resistivity of the high density chromic oxide refractory
C-1215 is plotted vertically against the temperature in
15 both degrees Centigrade and degrees Fahrenheit which is
plotted horizontally. Additionally, the electrical
resistivity of E glass is plotted in Figure 7. It will be
seen from the chart of Figure 7 that E glass has an
electrical resistivity of about 12 ohms per centimeter at
20 1482° C (2700° F) while the refractory at the same
temperature has an electrical resistivity of only about 2
ohms per centimeter. The refractory has an electrical
resistivity of about 12 ohms per centimeter at a
temperature of 1100° C (2012° F). Similarly, the Monofrax
25 E refractory has an electrical resistivity which is less
than that of E glass at the furnace operating temperature,
as shown in Figure 8.

Since the electrical resistivity of the
refractory lining portions 21-24 is less than the
30 electrical resistivity of the molten glass in the space 25,
the electrodes 30 and 32 will short-circuit through the
lower resistivity refractory in preference to flowing
through the molten glass of higher resistivity, and the
current from the power supply 31 will heat the refractory
35 rather than the molten glass. As a result, the refractory
will be heated and, if not melted, will slough off into the



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1 molten glass within the space 25 forming stones or other solid discontinuities in the molten glass.

The electrode current will not short-circuit through side walls 11 and the refractory 21 of the side walls since there is no appreciable flow of electricity between the electrodes of the same polarity carried by the side walls.

To prevent short-circuiting through the refractory lining 22 of the end walls 12 and the refractory lining 23 of the bottom wall 13, the lining 24 of the opening 14 and the lower bushing block 27, these areas preferably are water-cooled to a temperature at which the electrical resistivity of the refractory is increased appreciably. This is accomplished by means of heat exchangers 35 mounted on the exterior of the end walls 12 and heat exchangers 36 mounted on the exterior bottom surface of the bottom wall 13. These heat exchangers are of any conventional design and preferably are of the type which provide labyrinthian passages through which cooling water is flowed as indicated by the appropriate directional arrows of Figures 1, 2 and 3. By so cooling the side walls 12 and the bottom wall 13, the chromium oxide refractory lining is cooled to an extent such that the electrical resistivity of the lining is appreciably increased and short-circuiting through the lining is minimized.

As will be clear from the glass circulation diagram of Figures 2 and 3 and the above disclosure, the hottest glass and the most rapidly circulating glass are located above the plane of the electrodes 30 and 32. Thus, the most severe erosion and short-circuiting problems exist in the upper regions of the furnace 10, while the molten glass flows in cooler, essentially isothermal zones of relatively quiescent character along the furnace bottom 23 and through the outlet opening 14 and the bushing block 27. Accordingly, it is possible to line these areas with a compatible zircon refractory or similar high resistivity, non-water cooled refractory, if desired.



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1 In that version of the invention illustrated in
Figure 4 of the drawings, the same principles as described
in connection with Figures 1 through 3 are applied to a
forehearth 40 which is simply a glass channel
5 interconnecting a melting apparatus and a forming apparatus
and through which molten glass flows. In Figure 4, the
forehearth side walls 41 and bottom wall 42 are formed of a
suitable refractory, preferably a zircon refractory, as
described in connection with Figures 1 through 3 and the
10 side walls 41 and the bottom wall 42 are lined with a
lining 43 and 44, respectively, formed of an
erosion-resistant refractory of low electrical resistivity,
also as described in connection with Figures 1-3,
preferably a chromic oxide refractory such as those earlier
15 herein disclosed. The side walls 41 and 43 are pierced by
opposing electrically energizable electrodes 45 by means of
which the molten glass body 46 flowing through the
forehearth is heated to compensate for any heat losses
therein.

20 In accordance with the principles of this
invention and in order to prevent short-circuiting through
the bottom wall refractory lining 44, a heat exchanger 50
is provided in full surface contact with the undersurface
of the bottom wall 42, this heat exchanger being of the
25 same type as those earlier disclosed in connection with
Figures 1-3. The heat exchanger 50 cools the bottom wall
42 and the bottom wall lining 44 to an extent such that the
electrical resistivity of the lining 44 is substantially
increased and the tendency for short-circuiting between the
30 electrodes 45 by electrical flow through the lining 44 is
reduced.

 In that embodiment of the invention illustrated
Figures 5 and 6, the principles of the present invention
are embodied into a glass melting furnace having bottom
entering electrodes. More specifically, the furnace 60
35 comprises refractory side walls 61 and a refractory bottom
wall 62, each of the side walls 61 and the bottom wall 62



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1 being provided with an erosion-resistant lining 63 and 64,
preferably of a chromic oxide refractory material as
hereinbefore disclosed. One of the side walls 61 and its
lining 63 is provided with an exit port 65 through which
5 molten glass flows from the pool of molten glass 66
confined by the side wall linings 63 and the bottom wall
lining 64. This pool of molten glass 66 is surmounted by a
layer of particulate, unmelted glass batch 67.

Four electrodes 70 project upwardly through the
10 bottom wall 62 through the bottom wall lining 64 into the
molten glass pool 66, and these electrodes are energized by
a power supply (not shown) effective to energize the
electrodes with melting current of opposing polarity. The
number of electrodes and their geometric arrangement, as
15 illustrated in Figures 5 and 6, is schematic and is
intended merely as representative of any of the numerous
well known, commercially available bottom entry glass
heating electrode arrangements. Suitable electrode
arrangements and suitable power supplies for such
20 electrodes are well known in the art and are disclosed, for
example, in the U. S. patents to Gell, No. 3,683,093;
Orton, No. 3,395,237; and Holler et al, No. 3,836,689,
among others.

Since the electrodes 70 are of opposite polarity
25 and are carried by the common bottom wall 62 and 64 of the
furnace 60, short-circuiting through the low resistivity
bottom wall lining 64 is prevented by cooling the bottom
wall 62 by means of a heat exchanger 75 in full
face-to-face contact with the undersurface of the bottom
30 wall 62 and receiving cooling water for circulation
therethrough in the manner hereinbefore described. By
cooling the bottom wall 62 and the lining 64 for the bottom
wall, the resistivity of the bottom wall is increased to an
extent such that substantial short-circuiting through the
35 bottom wall 64 does not occur for the reasons and in the
manner heretofore described.



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1 In the furnace of the type illustrated in Figures
5 and 6, the coolest glass in the furnace is that adjacent
the bottom wall 62 and 64, since the heated glass from the
electrodes 70 rises in the furnace and flows by convection
5 away from the bottom wall. Further, glass supplied to the
forming apparatus (not shown) through the aperture 65 is at
a temperature which is substantially less than the
temperature of the glass at the upper ends of the
electrodes 70. Since the electrical resistivity of both
10 the molten glass of the pool 66 and of the bottom wall
lining 64 varies inversely and exponentially with
temperature, it will be seen that the glass at the primary
flow path between the electrodes is at a substantially
higher temperature than the temperature of the lining 64.
15 This temperature differential may range from about 156°C
(300°F) to about 267°C (500°F). If the heat exchanger 75
then cools the lining 64 to a greater extent, then this
temperature differential increases even further and the
relative resistivity of the lining 64 is increased to an
20 extent such that short-circuiting through the lining 64
will be minimized.

INDUSTRIAL APPLICABILITY

The present invention, while applicable to any
glass composition, is particularly applicable to low flux
25 content glasses, such as fiberglass compositions of
relatively high melting point. Where the glass composition
being melted is E glass, the hottest glass, i.e., that
glass above the electrodes 30, is generally at a
temperature on the order of 1482° C to 1538° C (2700° F to
30 2800°F) while the glass entering the bushing 28 is
substantially cooler, generally at a temperature on the
order of 1260° C to 1343° C (2300° F to 2450° F). A
typical "E" glass composition is as follows:

	<u>Ingredient</u>	<u>% by Weight</u>
35	SiO ₂	54.5
	Al ₂ O ₃	14.5
	Fe ₂ O ₃	0.4



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1	CaO	17.5
	Mgo	4.4
	Na ₂ O	0.5
	B ₂ O ₃	6.5
5	F ₂	0.3

Glasses other than E glass can be suitably utilized in the present invention. For example, C glass can be formed into fibers in the bushing 28. A typical C glass composition has the following composition:

10	<u>Ingredient</u>	<u>% by Weight</u>
	SiO ₂	65.1
	Al ₂ O ₃	3.7
	Fe ₂ O ₃	0.4
	CaO	14.3
15	Mgo	2.8
	Na ₂ O	8.1
	B ₂ O ₃	5.5

The refractory lining for the molten glass space 25 must be compatible with the glass being melted, i.e., the refractory must be inert to the glass composition at the operating temperature of the heating apparatus, and it must resist erosion by the glass particularly at the regions above the electrodes where the molten glass is rapidly circulated by the thermal convection currents generated by the heat imparted to the molten glass between the electrode tips.

It has been found that a dense chromic oxide refractory, such as that manufactured by Corhart Refractories of Louisville, Kentucky under the tradename "C-1215 Chromic Oxide Refractory" is compatible with E glass. This refractory has the composition:

30	<u>Ingredient</u>	<u>% by Weight</u>
	TiO ₂	3.8
	Cr ₂ O ₃	92.7
35	Fe ₂ O ₃	0.4
	Impurities	3.1



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1 The above refractory can also be used with C
glass of the above composition. Also compatible with C
glass, but not with E glass, is a refractory sold by The
Carborundum Company of Falconer, New York, under the
5 tradename "Monofrax E". This refractory has the
composition:

	<u>Ingredient</u>	<u>% by Weight</u>
	Cr_2O_3	79.7
	Mgo	8.1
10	Fe_2O_3	6.1
	Al_2O_3	4.7
	SiO_2	1.3
	Total Alkali	0.1

As above explained, the above-defined
15 refractories and other similar refractories are utilized as
the heating apparatus linings 21, 22, 23 and 24 because of
their compatibility with the desired glass compositions and
their high erosion resistance to the molten glass
circulating within the space 25 and flowing through the
20 outlet 14 and the bushing block 27 into the bushing 28,
particularly at the elevated temperatures at which the
glass is melted and conditioned within the furnace 10.
However, the electrical resistivity of the refractories of
the linings at the operating temperatures of the furnace 10
25 is less than the electrical resistivity of the molten glass
body in the space 25 and flowing through the furnace 10
into the bushing 28.

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C L A I M S

1. A method of heating molten glass, comprising:
10 a. providing a body of molten glass in a heating apparatus having glass-confining side and bottom walls provided with a refractory lining, the refractory lining having an electrical resistivity that decreases with an increase in its temperature and that, at the temperature of
15 the molten glass, is less than the electrical resistivity of the molten glass;

b. electrically heating the body of molten glass by heating electrodes of opposite polarity immersed in the molten glass; and

20 c. cooling the refractory lining of these walls interposed between electrodes of opposite polarity to substantially increase the electrical resistivity of said lining.

2. The method of Claim 1 wherein the electrodes
25 extend through opposing side walls of the heating apparatus, the electrodes of each of the respective side walls are all of the same polarity and the electrodes of the opposing wall are of opposite polarity, the opposing side walls ~~are joined by~~ spaced end walls, and the end
30 walls are cooled.

3. The method of Claim 1, wherein all of the electrodes extend through a single wall of the apparatus, and said single wall is cooled.

4. The method of Claim 1, wherein the heating
35 apparatus is a forehearth for conveying molten glass to a forming location, the electrodes extend through opposing side walls of the forehearth, the electrodes of the



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1 respective side walls are all of the same polarity and the electrodes of opposing walls are of opposite polarity, and the forehearth bottom wall is cooled.

5 5. An electrically energized glass melting furnace comprising:

a. a furnace having side and end walls provided with molten glass contacting surfaces formed of a chromic oxide refractory;

10 b. a plurality of electrically energizable electrodes carried by the side walls and projecting into the body of molten glass, the electrodes carried by each side wall all being of the same polarity; and

15 c. heat exchange means in heat exchange relation to the end walls and effective to cool the chromic oxide refractory to a temperature at which its resistivity is materially increased and short-circuiting through the refractory is substantially eliminated.

6. An electrically energized glass heating apparatus comprising:

20 a. a receptacle for molten glass having its walls lined with a refractory material which has an electrical resistivity that varies inversely with the temperature of the refractory and that, at the temperature of molten glass, has an electrical resistivity less than the electrical resistivity of the molten glass;

25 b. a plurality of electrically energizable electrodes of different polarity extending through at least one wall of said receptacle to be immersed in the body of molten glass; and

30 c. means for cooling the refractory material of those walls interposed between electrodes of differing polarity to reduce the temperature of the interposed refractory material to a temperature at which the electrical resistivity of the interposed refractory material is substantially increased.

35 7. An apparatus as defined in Claim 6, wherein the apparatus is a glass melting furnace, the receptacle



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1 has side, end and bottom walls lined with said refractory,
the electrodes extend through the side walls with the
electrodes of each side wall being of the same polarity and
the electrodes of opposing side walls are of different
5 polarity, and the end and bottom walls are provided with
the cooling means.

8. An apparatus as defined in Claim 6 wherein
the electrodes of different polarity extend through the
bottom wall only of the receptacle, and the bottom wall is
10 provided with the cooling means.

9. An apparatus as defined in Claim 5 wherein
the receptacle is a forehearth, the electrodes extend
through the forehearth side walls, and the bottom wall is
provided with the cooling means.

15 10. In a method of heating glass in a glass
heating apparatus having a refractory lining which, at the
apparatus operating temperature, has an electrical
resistivity less than the resistivity of the glass being
heated, the steps of:

20 a. electrically heating the molten glass by
electrodes inserted through the refractory lining of
opposing walls of the apparatus, the electrodes of a given
wall being of the same polarity and the electrodes of
opposing walls being of different polarity; and

25 b. maintaining the non-electrode bearing walls
of the apparatus at a temperature less than the temperature
of the molten glass and at which the resistivity of the
refractory lining of the non-electrode bearing walls is
substantially increased.

30 11. In a method of heating glass, the steps of:

a. maintaining a body of molten glass in contact
with opposing refractory walls pierced by heating
electrodes and joined by a joining refractory wall having
no electrodes, the electrodes of the opposing walls being
35 of different polarity, the refractory of said walls having
an electrical resistivity which is less than the



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1 resistivity of the glass at the temperature of the molten glass; and

b. cooling the joining wall to a temperature (a) that is less than the temperature of the molten glass and
5 (b) that materially increases the resistivity of the joining wall to a value at which appreciable short-circuiting through said joining wall does not occur.

12. In an apparatus for heating a body of molten glass, a heating space defined by side, end and bottom
10 peripheral walls; heating electrodes of the same polarity carried by each of the side walls and projecting into said space, the electrodes of opposing walls being of opposite polarity; a refractory lining for said peripheral walls, the lining having an electrical resistivity (a) that varies
15 inversely with the lining temperature and (b) that, at the operating temperature of the apparatus, is less than the resistivity of molten glass; and heat exchange means in heat exchange relation with the end and bottom peripheral walls for cooling the lining of said end and bottom walls.

20 13. The method of reducing short-circuiting in an electrically energized glass heating apparatus having spaced electrodes of opposite polarity and a refractory lining of relatively low electrical resistivity through which the electrodes extend comprising the step of cooling
25 those portions of the refractory lining which are interposed between electrodes of opposite polarity to an extent sufficient to materially increase the electrical resistivity of said lining portions.

30 14. In a method of operating an electrically heated glass heating furnace having a heating space circumscribed by refractory walls less than all of which bear heating electrodes of opposite polarity, the improvement of cooling the non-electrode bearing refractory walls of said furnace to an extent sufficient (a) to
35 materially increase the electrical resistivity of the cooled walls and (b) to reduce short-circuiting therethrough.



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1 15. The method of heating glass comprising the
steps of:

5 a. confining a pool of molten glass in contact
with side, end and bottom walls of a chromic oxide
refractory;

10 b. heating the pool by electrodes projecting
through the side walls into said pool, the electrodes of
each side wall being of the same polarity and the
electrodes of the opposing side walls being of opposite
polarity;

15 c. cooling the chromic oxide refractory of said
end walls and said bottom wall only to a temperature at
which the electrical resistivity of said chromic refractory
is materially increased,

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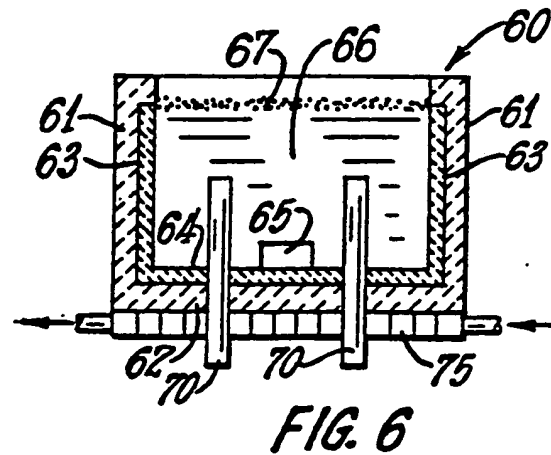
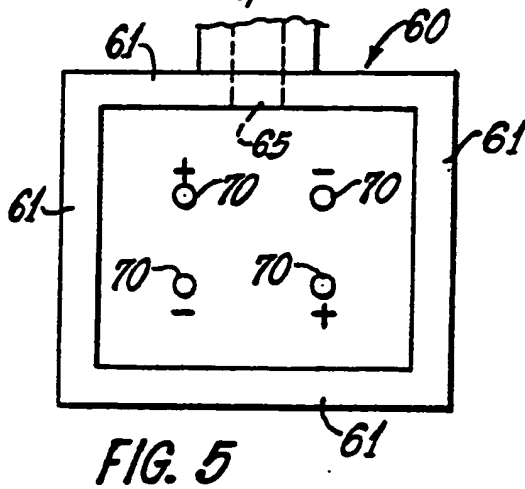
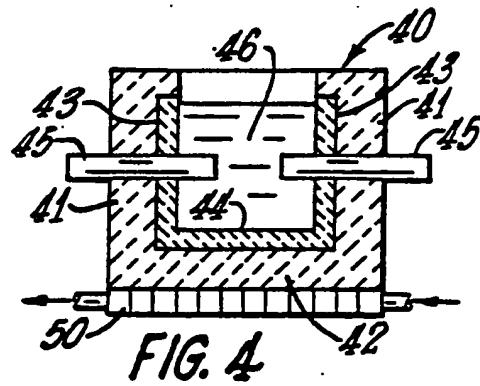
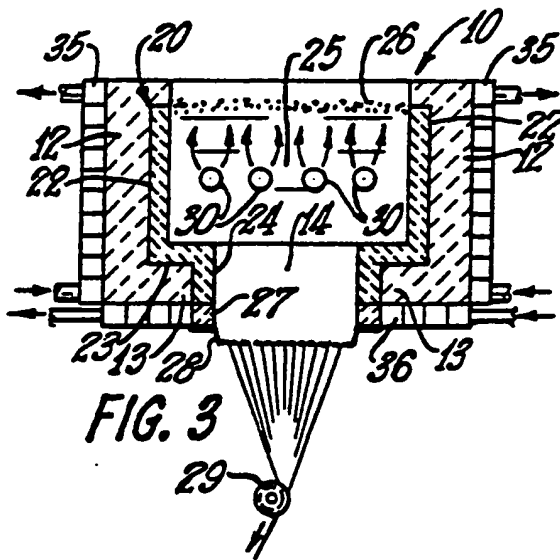
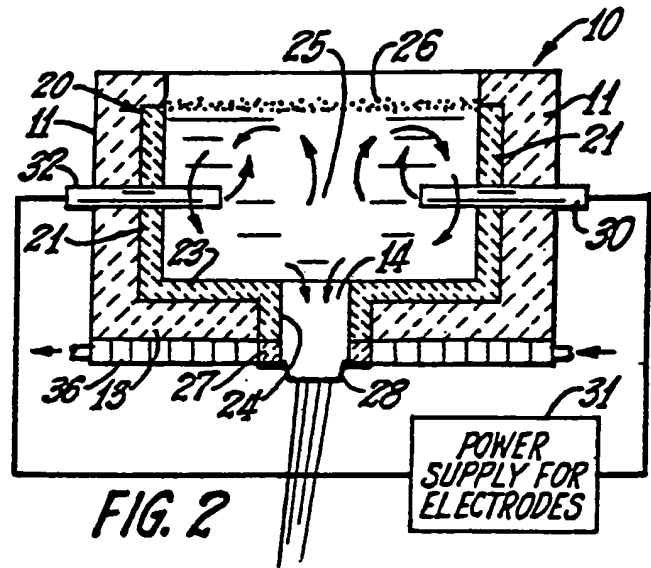
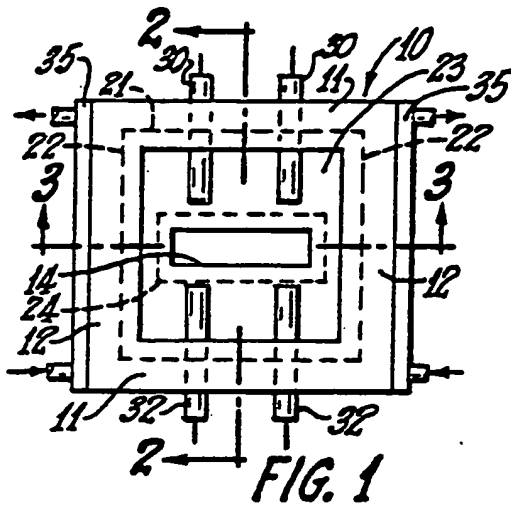
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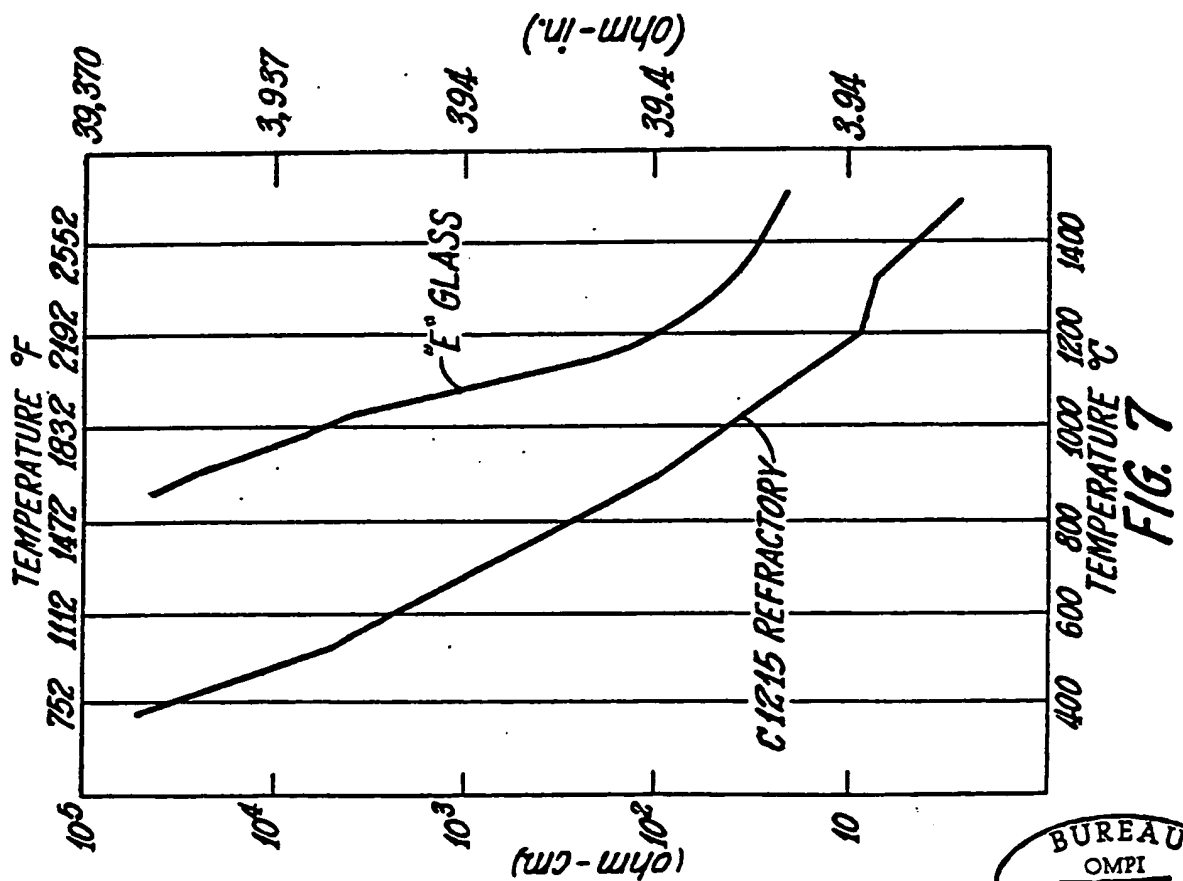
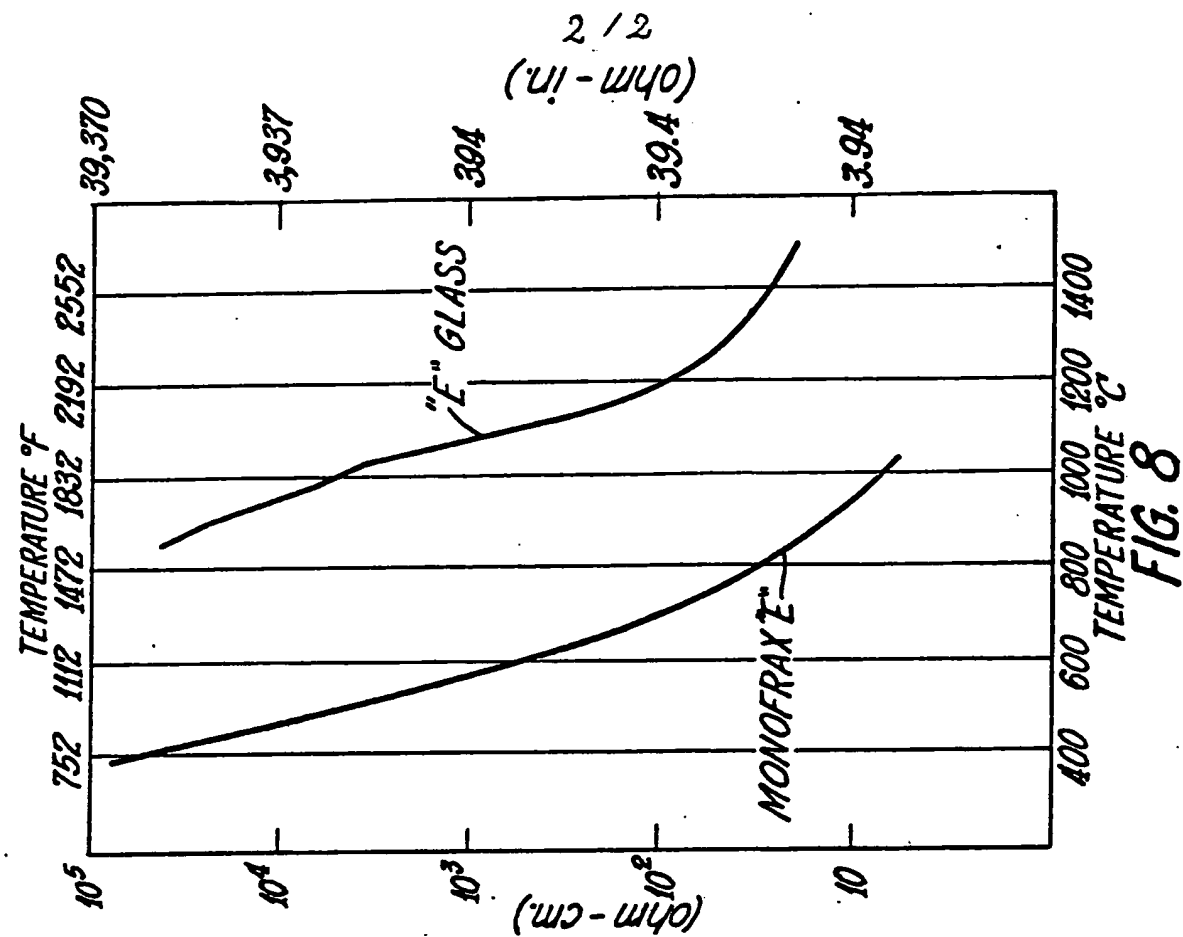
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INTERNATIONAL SEARCH REPORT

International Application No PCT/US 84/00591

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ³ : C 03 B 37/09; C 03 B 5/027; C 03 B 5/42; C 03 B 5/44; C 03 B 7/06																				
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched ⁴</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 20%; border-bottom: 1px solid black;">Classification System</th> <th style="border-bottom: 1px solid black;">Classification Symbols</th> </tr> <tr> <td style="vertical-align: top; padding: 5px;">IPC³</td> <td style="padding: 5px;">C 03 B 5/027; C 03 B 5/42; C 03 B 5/44; C 03 B 37/09; C 03 B 7/02; C 03 B 37/08</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵</div>			Classification System	Classification Symbols	IPC ³	C 03 B 5/027; C 03 B 5/42; C 03 B 5/44; C 03 B 37/09; C 03 B 7/02; C 03 B 37/08														
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; border-bottom: 1px solid black;">Category ⁶</th> <th style="width: 60%; border-bottom: 1px solid black;">Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 30%; border-bottom: 1px solid black;">Relevant to Claim No. ¹⁸</th> </tr> <tr> <td style="vertical-align: top; padding: 5px;">P,X</td> <td style="padding: 5px;">WO, A, 84/00746 (OWENS-CORNING FIBERGLASS CORPORATION) 1 March 1984, see figures 4,5; page 14, lines 30-37; pages 15,16, lines 1-21; claims 1,2,11,19-24; new claims 36,44</td> <td style="vertical-align: top; padding: 5px;">1-15</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">FR, A, 2457462 (SIDONS INDUSTRIES LTD.) 19 December 1980, see figures 1,2,3; page 5; page 7, lines 16-39; page 8</td> <td style="vertical-align: top; padding: 5px;">1,5,6,10</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A, 2686821 (J.C. McMULLEN) 17 August 1954, see the entire document</td> <td style="vertical-align: top; padding: 5px;">1,5,6,10</td> </tr> <tr> <td style="vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">GB, A, 803457 (SCHMIDT'SCHE HEISSDAMPF-GESELLSCHAFT) 22 October 1958, see the entire document</td> <td style="vertical-align: top; padding: 5px;">1,5,6,10</td> </tr> <tr> <td colspan="3" style="text-align: center; padding: 10px;">-----</td> </tr> </table>			Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	P,X	WO, A, 84/00746 (OWENS-CORNING FIBERGLASS CORPORATION) 1 March 1984, see figures 4,5; page 14, lines 30-37; pages 15,16, lines 1-21; claims 1,2,11,19-24; new claims 36,44	1-15	A	FR, A, 2457462 (SIDONS INDUSTRIES LTD.) 19 December 1980, see figures 1,2,3; page 5; page 7, lines 16-39; page 8	1,5,6,10	A	US, A, 2686821 (J.C. McMULLEN) 17 August 1954, see the entire document	1,5,6,10	A	GB, A, 803457 (SCHMIDT'SCHE HEISSDAMPF-GESELLSCHAFT) 22 October 1958, see the entire document	1,5,6,10	-----		
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<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁹ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"d" document member of the same patent family</p> </div> </div>																				
IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">Date of the Actual Completion of the International Search ²</td> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">Date of Mailing of this International Search Report ²</td> </tr> <tr> <td style="text-align: center; padding: 5px;">25th July 1984</td> <td style="text-align: center; padding: 5px;">15 AOUT 1984</td> </tr> <tr> <td style="border-bottom: 1px solid black; padding: 5px;">International Searching Authority ¹</td> <td style="border-bottom: 1px solid black; padding: 5px;">Signature of Authorized Officer ²⁰</td> </tr> <tr> <td style="text-align: center; padding: 5px;">EUROPEAN PATENT OFFICE</td> <td style="text-align: center; padding: 5px;"> G.L.M. Kruidenberg </td> </tr> </table>			Date of the Actual Completion of the International Search ²	Date of Mailing of this International Search Report ²	25th July 1984	15 AOUT 1984	International Searching Authority ¹	Signature of Authorized Officer ²⁰	EUROPEAN PATENT OFFICE	 G.L.M. Kruidenberg										
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ANNEX TO THE INTERNATIONAL SEARCH REPORT C.A.

INTERNATIONAL APPLICATION NO. PCT/US 84/00591 (SA 7019)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 09/08/84

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A- 8400746	01/03/84	AU-A- 1827383	07/03/84
FR-A- 2457462	19/12/80	GB-A, B 2051325	14/01/81
		DE-A- 3019812	27/11/80
		JP-A- 56049877	06/05/81
		US-A- 4375449	01/03/83
		SE-A- 8003721	24/11/80
		CA-A- 1153409	06/09/83
US-A- 2686821		None	
GB-A- 803457		None	

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